

Dental age estimation of growing children by measurement of open apices: A Malaysian formula

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Abstract

Background: Age estimation is of prime importance in forensic science and clinical dentistry. Age estimation based on teeth development is one reliable approach. Many radiographic methods are proposed on the Western population for estimating dental age, and a similar assessment was found to be inadequate in Malaysian population. Hence, this study aims at formulating a regression model for dental age estimation in Malaysian children population using Cameriere's method. **Materials and Methods:** Orthopantomographs of 421 Malaysian children aged between 5 and 16 years involving all the three ethnic origins were digitalized and analyzed using Cameriere's method of age estimation. The subjects' age was modeled as a function of the morphological variables, gender (g), ethnicity, sum of normalized open apices (s), number of tooth with completed root formation (N_0) and the first-order interaction between s and N_0 . **Results:** The variables that contributed significantly to the fit were included in the regression model, yielding the following formula: $\text{Age} = 11.368 - 0.345g + 0.553N_0 - 1.096s - 0.380s.N_0$, where g is a variable, 1 for males and 2 for females. The equation explained 87.1% of total deviance. **Conclusion:** The results obtained insist on reframing the original Cameriere's formula to suit the population of the nation specifically. Further studies are to be conducted to evaluate the applicability of this formula on a larger sample size.

Key words: Age estimation, Cameriere's method, dental age, forensic odontology

Introduction

The age of an individual has a significant role in clinical, medico-legal, forensic and anthropological applications. In instances where chronological age is unknown, undocumented or missing, several growth parameters based on skeletal indicators such as

hand-wrist bone ossification, changes in pubic symphysis, fusion of cranial sutures, dental maturation, and somatic indicators (like menarche and endocrinal changes) are utilized for probable age estimation.^[1] However, several of these indicators demonstrate considerable variation, which is often influenced by environmental and genetic factors. However, the dental maturation serves to be the reliable and most accurate means, especially because of its unique nature of incremental formation and periodic mineralization that can be well defined. This patterned and progressive calcification of the developing tooth is independent of the local and environmental influences, as well as from the somatic growth.^[2] Therefore teeth are counted as the least variable bio-indicator for age assessment. This is further reassured by the sustainability of dental hard tissues against environmental insults.^[3]

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Various methods of dental age estimation are proposed by Demirjian, Nolla, Willems and Haavikko for growing individuals.^[4-7] In all these methods, radiographs were used as an evidence to analyze the progressive sequence of teeth development and each stage of development was coded and scored. These scores were manipulated meticulously to derive the dental age of an individual and relative with the chronological age, with acceptable error limits. However, all these methods dated back a few decades and the change in the growth trend of the current generation alarmed for formulating a newer method of dental age assessment.^[8] In 2006, Cameriere *et al.* published a new concept of estimating chronological age in children by measuring the open apices in seven mandibular teeth on radiographs, which gave reliable estimates of age in 455 Italian Caucasian children.^[9] Perhaps, the reliability of Cameriere's method was evaluated on several sample groups from different nationalities, to reveal the fact that the original regression model formulated by Cameriere is not always suitable for other countries as tooth development differed among population and exhibited variation among ethnic groups and regional locations.^[10] They were further influenced by dietary practice, socioeconomic status, nutritional habits, and lifestyle.^[11] Few authors therefore modified Cameriere's regression model with newer samples to suit their population and suggested Cameriere's method to be the most accurate method for the population of current decade.^[12-14] Although these studies validated the method, they also highlighted the need to develop a discrete regression model for the study samples of each country. Thus, in this study we attempted to formulate a regression model for the growing children of Malaysian population.

Materials and Methods

The orthopantomographs of 516 healthy Malaysian children aged between 5-16 years from Malay, Chinese, and Indian ethnicity were analyzed. Children who were of Malaysian origin at least for two generations and free from any medical conditions were included in the study. Radiographs that were unclear, with gross pathology, or having history of orthodontic treatment were excluded. Only 421 radiographs (81.6%) satisfied the criteria and were included in the study. Table 1 shows the distribution of

Table 1: Distribution of panoramic radiographs in the study samples

Age group	Malay		Chinese		Indian	
	Male	Female	Male	Female	Male	Female
5-7	11	13	11	11	8	10
7-9	15	19	6	14	7	11
9-11	11	11	10	8	11	13
11-13	10	13	9	12	15	15
13-15	14	38	17	31	21	26
Total	61	94	53	76	62	75
	155		129		137	
	421					

panoramic radiographs by gender, age, and ethnic group. All the radiographs were digitalized using HP Scanjet G4050 Backlight scanner and the images were recorded on computer files and processed by a computer aided drafting program (Adobe Photoshop Version 7). The Institution Ethical Committee granted ethical approval. [Reference: AUHAEC 77/FOD/2012].

All the 421 radiographs were evaluated in accordance with Cameriere's *et al.*,^[13] for dental age estimation. In brief, the radiographs of 7 left permanent mandibular teeth were assessed. Teeth which were formed completely, with closed apical ends, were ascertained as N_0 . The teeth with incomplete root formation and hence open apex were evaluated in the following order. For teeth with single root, A_i , where $I = \text{tooth } 1,5$, the distance between the inner side of the open apex was measured. For teeth with two roots, A_{im}, A_{id} , where $I = \text{tooth } 6,7$ and $m = \text{mesial root}$, $d = \text{distal root}$, the sum of the distances between the inner sides of the two open apices were measured, as depicted in Figure 1. In order to manipulate the accountable differences in magnification and angulations during radiographic imaging, measurements were normalized by dividing by the tooth length (L_i , where $I = \text{tooth } 1, \dots, 7$). Finally, dental maturity was evaluated using normalized measurements of all the seven permanent left mandibular teeth ($x_i = A_i/L_i$, $I = \text{tooth } 1, \dots, 7$), the sum of normalized open apices (s) and the number (N_0) of teeth with complete root development. Measurements were carried out by two different observers and inter and intra-observer reliability was checked on 10 independent panoramic radiograph samples.

Statistical analysis

All the morphologic variables, N_0 , s , x_i , where $I = \text{tooth } 1, \dots, 7$, the subject's gender and ethnic group were entered in an Excel file and were used as predictive variables for age estimation in sequential statistical analysis. The

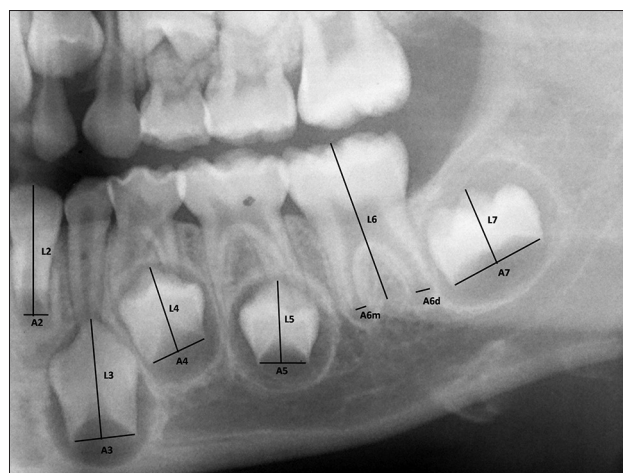


Figure 1: Cameriere's method of measurement for the teeth with open apices

chronological age is calculated by subtracting the date of birth from the date of radiograph and was recorded. The inter- and intra-observer reliability of the sum of normalized open apices (s) was studied by using concordance correlation co-efficient, and κ statistics was used to measure intra and inter observer reliability of the number for the seven left permanent mandibular teeth with root development complete (N_0).

To obtain an estimate of age as a function of the morphological variables and subject's gender and ethnicity, a multiple linear regression model with first-order interactions was developed by selecting those variables that contributed significantly to age estimations by means of stepwise selection method. An analysis of covariance was then utilized to study possible interactions between significant morphological variables and gender and ethnicity. Statistical analysis was performed with SPSS version 16.0 and significant threshold was set at 5%.

Results

Inter- and intra-observer data obtained by re-examining the panoramic radiographs displayed no statistically significant difference. Indeed, in the seven left permanent mandibular teeth with completed root development (N_0), no disagreement was observed between the two measurements made by the observers, i.e. $\kappa=1$. The estimated concordance correlation coefficient (\pm standard deviation) for the sum of normalized open apices (s) was $\rho_c = 0.997 \pm 0.209$ between the observers and $\rho_c = 0.949 \pm 0.193$ for the paired set of measurements made by the same observer, as illustrated in Figures 2 and 3. Subject's age was modeled as a function of gender (g), nationality, and morphological variables and to optimize the model, a stepwise regression analysis was applied. The results demonstrated in Table 2 shows the gender (g) and the variables s, N_0 and the first order interaction between s and N_0 contributed significantly to the fit. With regard to the ethnicity, regression analysis pointed

out no statistically significant difference. Thus, only the variables that contributed significantly were included in the regression model, yielding the following linear regression formula for Malaysian population.

$$\text{Age} = 11.368 - 0.345 g + 0.553 N_0 - 1.096 s - 0.380 s.N_0 \tag{1}$$

Where, g is a variable equal to 1 for boys and 2 for girls.

Equation 1, with the considered variables, explained 87.1% ($R^2 = 0.871$) of total deviance. Median of the residuals (observed age - predicted age) was -0.01 years, with an interquartile range (IQR) of 0.98 years. The residual pane [Figure 4] showed no obvious pattern. The observed verses predicted plot [Figure 5] showed that the regression model fitted the trend of the data reasonably well. Therefore, the diagnostic plots supported our chosen model.

Discussion

Though chronological age is essential in many situations, undocumented or missing birth data alerts the need to estimate the age of an individual. This is becoming increasingly important in forensic science and clinical aspects. Several morphological methods have been developed to estimate the same, but accuracy of these methods are defined by their ability to arrive at an age

Table 2: Stepwise regression analysis predicting chronological age from chosen predictors for the Malaysian population

Coefficients	Value	SE	t value	P	95% C.I.	
					Lower	Upper
Intercept	11.368	0.328	34.6	<0.001	10.72	12.01
g	-0.345	0.099	-3.5	0.001	-0.54	-0.151
N_0	0.553	0.05	0.4	<0.001	0.455	0.652
s	-1.096	0.092	-11.9	<0.001	-1.277	-0.916
s. N_0	-0.380	0.044	-8.7	<0.001	-0.466	-0.294

s. N_0 =Interaction between variables s and N_0 . SE: Standard error

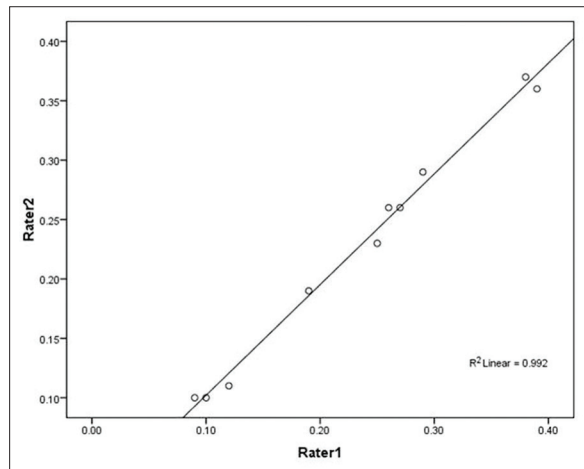


Figure 2: Plot for Inter-observer measurements

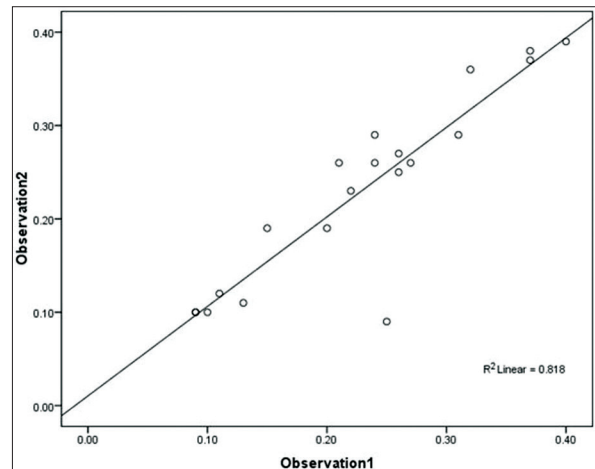


Figure 3: Plot for Intra-observer measurements

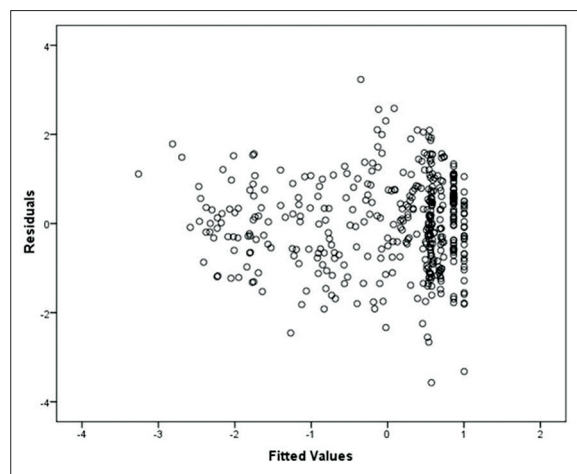


Figure 4: Plot of residuals against fitted values using regression model (Equation 1)

as close to the chronological age, within acceptable error limits.^[2,15,16] Among those, dental estimation is widely accepted as the most accurate and reliable scientific method, as it relates closely with chronological age than any other maturity indicators and is the least variable method compared to others.^[17] Basically, there are two concepts in dental age assessment. One is by assessing the age of tooth eruption in the oral cavity, and the other is by recording the stages of root and crown mineralization in primary and permanent dentition. The former possesses the disadvantage of being affected by local factors during the process of tooth eruption, i.e. premature deciduous tooth loss, ankyloses, etc.; while the latter is a progressive phenomenon and easily definable by the staging of calcification and therefore is the most reliable dental indicator.^[2]

It has been reported that growth of a child may be influenced by several factors including genetic, nutritional, racial, hormonal, climatic, social, etc., Among the several maturity bio-indicators usually examined, teeth are least influenced by all these factors. It is to be counted that various dental age estimation methods recommended in the past did not provide a common formula for the population of the whole world.^[18-20] These methods also differed in their accuracy when different populations were considered. Hence this paper focuses on improvement of the method developed by Cameriere *et al.* to suit the Malaysian children population.

Malaysia prides itself on being a multi-cultural country, with mixed ethnicity, consisting of Malays (50.7%), Chinese (23.1%), Indians (6.9%), and the remaining constituting minor ethnic groups and foreigners.^[21] With every possible difference in environmental factors, dietary habits, growth rates and ethnicity, their influence on dental variables must be considered in formulating a linear regression model in the Malaysian population. However, analysis of covariance for ethnicity showed no significant influence on age estimation in our study

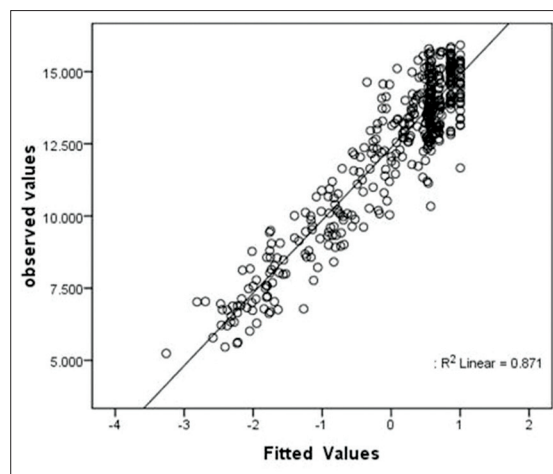


Figure 5: Plot of the observed against predicted values using Equation 1

population. Hence, ethnicity was not included as a factor in the model equation, but gender displayed significant influence on age estimation. All normalized open apices showed a significant correlation with age, hence, they entered the model equation (equation 1) through the sum of normalized open apices (s) and number (N_o) of teeth with complete root development. The result allowed the use of a single equation to estimate the dental age of the Malaysian children population, independent of their ethnic origin.

The European model states that the developmental stage of second premolar had a significant correlation with age estimation, and hence was included as a variable in the regression equation.^[9] In the Indian formula proposed for dental age estimation, the region of the country was considered to have significant correlation with age estimation.^[14] In particular, no ethnicity or second molar variables were significant. Our results showed that not all the variables used for the European and Indian models were significant predictors of age estimation in the Malaysian sample.^[9,14]

This study and the results obtained are in agreement with other studies and insist on reframing the original Cameriere's formula to suit the population of the specific nation, and to focus on the influential variables that could possibly alter the development of tooth tissues to create a linear regression model according to the children of other nations. Further studies are to be conducted to evaluate the applicability of this formula on a larger sample size and to compare the reliability of this model with other methods of age estimation.

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